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Incidence and Distribution of Postcranial Fractures in the Prehistoric Population of San Pedro de Atacama, Northern Chile

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ABSTRACT Trauma incidence analysis in skeletal populations has been very popular among skeletal biologists during the last two decades. In this context, the work of Lovejoy and Heiple ([1981] Am. J. Phys. Anthropol. *55:*529–541) has been quoted as a landmark because their analysis rested on a populational approach, avoiding simple assumptions about cause and etiology. In this study, we apply to the prehistoric population of San Pedro de Atacama, northern Chile, an approach similar to that carried out by Lovejoy and Heiple (1981). The results obtained point to a peak of risk of fractures among old people, estimated age around 45 years. The distribution of fractures by sex and age suggests that the prevailing etiology is related to accidents and not violence. When the frequencies of fractures are compared, the Libben population shows a much higher incidence than the Atacamenean population. It is suggested that this difference can be explained by peculiarities of the subsistence economies of the two populations. Am J Phys Anthropol 109:253–258, 1999.

The pioneering studies of Saul (1976) and Edynak (1976), which investigated life style among skeletal populations, stimulated many North American physical anthropologists to do the same (Neves, 1984; Larsen, 1987; Iscan and Kennedy, 1989). Among the osteological markers explored to reconstruct past lifeways from skeletons, trauma has received special attention (Merbs, 1989; Lovell, 1997). Initially, analysis of traumatic injuries in skeletal populations was primarily descriptive, resting on the presentation of individual cases and their probable ultimate (behavioral) causes. In this context, as affirmed by Merbs (1989) the work of Lovejoy and Heiple (1981) has to be seen as a turning point. These authors presented the first epidemiological analysis of fractures in a skeletal population (Libben site) and determined quantitatively the rate, pattern of occurrence and level of risk of traumatic injuries.

Instead of looking for specific behaviors behind specific occurrences of fractures, Lovejoy and Heiple (1981) concentrated their efforts in recovering patterns of collective behaviors that could explain the general pattern of fracture distribution in the Libben population. They reached two major conclusions. The first was that the pattern of fracture occurrence pointed to an etiology related to everyday accidents and not to violence, and the second was that years-at-risk analysis in the Libben population generated a graph characterized by an A-type curve superimposed on a U-shaped curve.

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The latter would correspond to high activity levels of adolescence and old-age fractures of senescence, while the A curve would correspond to work-related accidents of middle-aged males.

In this study, we attempt a similar analysis to that carried out by Lovejoy and Heiple (1981). Our focus is on the prehistoric population of San Pedro de Atacama, Northern Chile. This attempt is part of a long-term research project that aims, through an osteobiographic approach, to recover the life style and elements of social organization of the Atacamenean population.

ARCHAEOLOGICAL CONTEXT

The region of San Pedro de Atacama is located in the Atacama desert, northern Chile, and is characterized by the presence of a cluster of several small oases that attracted the settlement of human communities after the adoption of cultivation in that portion of the Andes (Llagostera and Costa, 1984). The first permanent prehistoric settlements in the region date back to 500 BC and mark the beginning of the San Pedro culture, which reached a climax between AD 400 and 900. The collapse of the Atacamenean society coincided with the arrival of Spaniards in the Atacama desert in the sixteenth century. When the first contacts with the Europeans were undertaken, San Pedro de Atacama was still inhabited by indigenous populations, organized in traditional political and social units called *Señorios* (Le Paige, 1965). The prehistory of San Pedro de Atacama is characterized by phases of local developments alternated with phases of external influence from the major Andean empires (Núñez, 1992).

The Tiwanaku influence in San Pedro de Atacama lasted from AD 400 to 900 and coincided with the most prosperous economic phase of the Atacamenean society. The relationships between San Pedro de Atacama and that altiplanic state seem to have been peaceful (Núñez, 1992; Neves et al., 1996). As in other areas of the south-central Andes, the local communities were gradually absorbed by the expanding Tiwanaku empire (Browman, 1980; Stanish and Steadman, 1994).

The absorption of the Atacameans by the Tiwanaku sphere of influence occurred primarily through religion and trade (Berenguer et al., 1980). San Pedro de Atacama became a strategic nodule for the llama caravans that linked the center of the Tiwanaku empire in Bolivia with northwest Argentina and served as an important source of minerals for altiplanic metallurgy. Atacameneans took advantage of this situation and intensified their commercial activities. Le Paige (1965), Llagostera and Costa (1984), and Núñez (1992) determined that a general enrichment in the area can be inferred from the presence of sophisticated burial items. Neves and Costa (1998) demonstrated an increase in the stature of the local population by this time, which reinforces the idea of a general economic improvement in San Pedro under Tiwanaku influence. The subsistence economy, however, was not significantly changed. Neves et al. (in press) have shown that the exposure of the Atacameneans to stressful activities leading to trauma remained the same as before.

The Inca influence in San Pedro de Atacama, which started in 1450, was meager in comparison with that of Tiwanaku. In fact, it lasted only a few decades, because it was suddenly interrupted by the arrival of Spaniards in AD 1536. As in the case of Tiwanaku, the Inca influence was peaceful.

During the existence of the Atacameneans as a self-governing society, everyday life relied primarily on camelid raising, on small, irrigated garden cultivation of corn, potato, quinopod, and squash, and on the gathering of fruits of *algarrobo* and *chañar*. This subsistence economy was complemented by trading with people in southern Bolivia, northwestern Argentina, and the Pacific rim of the Atacama desert itself. It is important to note that all these activities were carried out in a desertic and semidesertic geographic area characterized by a very irregular and rough terrain.

MATERIALS AND METHODS

The skeletal material used in this work totals 244 individuals (161 adults and 83 subadults) uncovered from the sites of Solcor-3, Quitor-6, and Coyo-3. These three sites are located near San Pedro de Atacama

TABLE 1. Individuals bearing fractures in San Pedro de Atacama and in Libben site (using bones as unit of analysis)[1]

	San Pedro de Atacama			Libben		
Bone	Observed fractures	N	f(frac) %	Observed fractures	N	f(frac) %
Clavicle	9	408	2.21	15	260	5.77
Humerus	1	423	0.24	3	450	0.67
Radius	17	402	4.23	20	369	5.42
Ulna	17	412	4.13	11	351	3.13
Femur	3	427	0.70	9	347	2.59
Tibia	3	403	0.74	5	349	1.43
Fibula	3	404	0.74	9	257	3.50

[1]f(frac) % is the percentage of observed fractures.

TABLE 2. Age and sex of individuals bearing fractures in the Atacama population[1]

	N (individuals bearing fractures)	Females (X age)	Males (X age)	Combined	% female	% male
Clavicle	9	37	41	39	56	44
Humeri	1	38	—	38	100	0
Radius	15	39	40	40	53	47
Ulna	15	40	38	39	60	40
Femur	3	44	33	39	67	33
Tibia	3	40	43	42	67	33
Fibula	3	—	35	35	0	100
all	40	34	33	34	57	43

[1]X age is the mean age of those individuals bearing fractures.

and were excavated by archaeologists during the last 20 years. They cover the period from AD 250–1240. Solcor-3 has two components: one representing the pre-Tiwanaku period (AD 250–480) and another representing the period under the influence of Tiwanaku (AD 480–920) (Llagostera et al., 1988). Quitor-6 and Coyo-3 represent the immediate post-Tiwanaku period (pre-Inca) and are dated from AD 920–1240 (Costa, 1988). In a work in press, Neves et al. have demonstrated that there are no significant differences between these periods in terms of the incidence of trauma. This allowed us to pool together the skeletal materials from the three sites and treat them as one sample.

All skeletons were screened for visible, postcranial, healed fractures by two of the authors (W.A.N. and M.A.C.), using Ortner and Putschar (1981) as a standard reference. The skull fractures were treated in a separate paper (Neves et al., 1996) and were used as indicators of interpersonal violence.

The incidence of fractures was analyzed in two ways: by the number of individuals (by age and by sex) and by the number of bones. Fractures per years of risk were calculated as described by Lovejoy and Heiple (1981).

The significance of differences in fractures between the Atacameans and the Libben people was determined by chi-square tests.

RESULTS AND DISCUSSION

Fracture rate

In order to look at any patterning in the occurrence of fractures in San Pedro de Atacama, we calculated the frequencies of incidence using bone as the unit of analysis.

Table 1 presents the number of bones analyzed and the number of injured bones observed in comparison with the data obtained by Lovejoy and Heiple (1981). As can be seen, radii and ulnae were the most affected bones, while humeri were the least affected in San Pedro de Atacama. Rates can be seen to vary widely, from a low of 0.24% in the humerus to 4.23% in the radius.

Unlike what Lovejoy and Heiple (1981) found, clavicles were not the most affected site. Another marked difference is that while Libben site fibulae were twice more affected than tibiae, in San Pedro de Atacama both bones showed similar rates of injuries.

However, when chi-square tests were applied to these observations, only the clavicle ($P = 0.0278$) and the fibula ($P = 0.0219$) showed significant differences.

It is also worth noting that the Libben population was more affected by fractures than the population of San Pedro de Atacama. The mean incidence of fractures over all seven analyzed bones is 3.22% in the former and 1.86% in the latter sample. This is a highly significant difference ($P = 0.0041$).

While it would be worthwhile to compare the frequencies obtained in our study with those obtained from other prehistoric groups, this is hampered by the fact that other reports on prehistoric fractures rarely provide suitable data, as was also noted by Lovejoy and Heiple (1981).

Sex, age, and side

The mean age at death and the sex ratio were calculated for each of the major long bones (Table 2). Apart from the humerus and the fibula, no other bone suggested differences in fracture incidence by sex. How-

TABLE 3. Fractures per years at risk[1]

Age	dx	Person years at risk	Observed fractures	Total person years at risk	Fractures per person years at risk $\times 10^{-5}$
0–15	67	7.5	0	502.5	0
16–20	17	15	1	255	392
21–25	11	22.5	2	247.5	808
26–30	20	27.5	5	550	909
31–35	48	32.5	13	1560	833
36–40	33	37.5	13	1237.5	1051
41–45	27	42.5	8	1147.5	697
46–50	13	47.5	10	617.5	1619
51–55	6	52.5	1	315	317
55+	2	57.5	0	115	0

[1]dx is the number of individuals with that age.

ever, a Fisher's exact test indicated that these differences were not statistically significant ($P = 0.2536$ and $P = 0.4510$, respectively). The sex ratio of all individuals with fractures also did not differ significantly ($P = 0.1689$). These findings parallel those found by Lovejoy and Heiple (1981).

The bone with the lowest mean age at death among individuals with fractures was the fibula, while the oldest mean age was found for the tibia. These results are in marked contrast with those obtained by Lovejoy and Heiple (1981), who detected the lowest mean age for the femur and the oldest mean age for the radius. Also, the overall mean age at death of individuals bearing fractures in San Pedro de Atacama was 34 years, while in Libben the mean age at death was 37 years. In other words, although individuals were less affected by fractures in San Pedro de Atacama, they tended to be affected earlier in life when compared with Libben site.

A comparison was also made of fracture rates by side (data not shown). No significant differences were found. Lovejoy and Heiple (1981) found side-significant difference for radius and assumed this difference was related to the predominance of right-handedness in the Libben population.

Analysis by years at risk

Table 3 presents the estimation of fractures per years at risk, while Figure 1 depicts graphically the same information. As noted by Lovejoy and Heiple (1981), if fractures were to have occurred at a constant rate, independent of age, fractures per years at risk should show the same distribution as the total accumulated years at risk in each age class. This was not the case either at Libben or San Pedro de Atacama, as can be seen in Figure 1.

However, the curve obtained for San Pedro de Atacama differs markedly from that of Libben site. In the Libben site, the overall curve, adjusted for years of risk, seems to conform to the curve pattern described by Buhr and Cooke (1959), where an age-related curve of the A type, associated with work-related accidents, is superimposed upon an L and a J curve related to two peaks of incidence: one during youth, caused by hyperactivity in the adolescence, and another with the post-wage-earning period, caused by senescence.

In the case of San Pedro de Atacama, the curve obtained shows clearly the A and the J component but not an easily recognizable L component. Surprisingly, for some unknown reasons, late adolescents and early adults were not submitted to a high rate of risky activities in the Atacama desert.

SUMMARY AND CONCLUSIONS

We stated earlier that the study of fractures in skeletal populations has become very popular in the international anthropological literature of the last two decades (Lovell, 1997). Although most of these studies were descriptive in nature, Lovejoy and Heiple's (1981) work opened a new avenue in this context: the possibility of treating fractures in a populational and quantifiable manner (Merbs, 1989) by avoiding simple assumptions about cause and etiology.

In this study, we analyzed trauma in the prehistoric population of San Pedro de Atacama, northern Chile, in a manner similar to that undertaken by Lovejoy and Heiple (1981). Our research aimed at characterizing the incidence and distribution of fractures in the Atacama desert and compared them with those of the Libben site.

The most important conclusions obtained can be summarized as follows.

1. The pattern of fractures suggests that most occurred through accidental trauma during the everyday life rather than from interpersonal violence. As in Lovejoy and

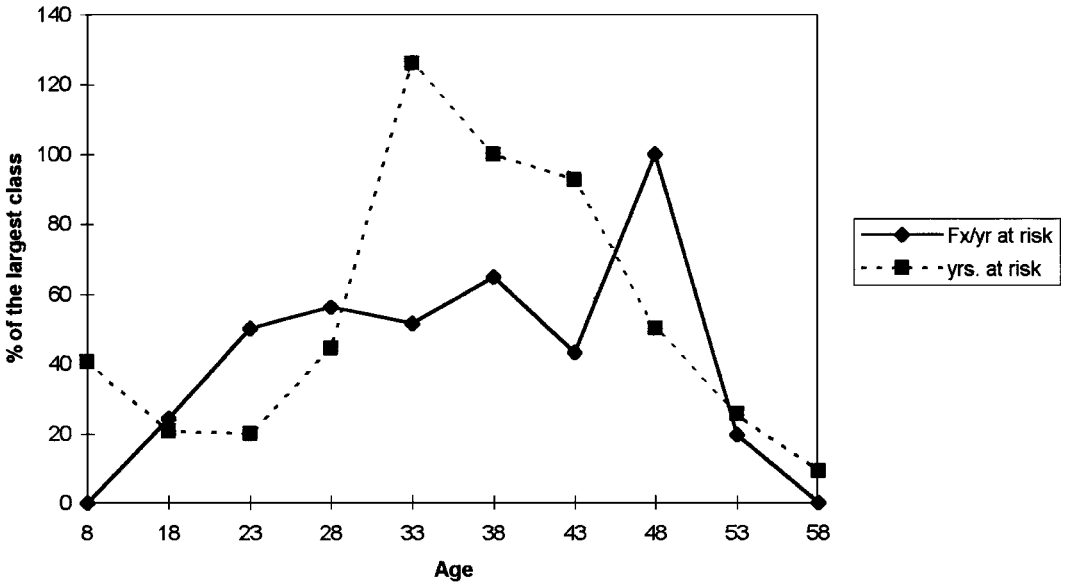

Fig. 1. Comparison of summed year of risk (broken line) with number of fractures per years of risk (solid line)

Heiple (1981), the evidence for this conclusion is the lack of sexual differences in the incidence of fracture, the absence of fractures during childhood and early adolescence, and the fact that the most affected portion of the population was elderly.

2. Use of a years-at-risk analysis suggests only one period of elevated fracture risk: above 45 years. This probably reflects old-age fractures of senescence and contrasts with Lovejoy and Heiple (1981), whose analysis revealed two peaks in the Libben population: one during late adolescence and early adulthood and the other above 45 years. Lovejoy and Heiple argue that the peak around final adolescence and the beginning of adult life is related to hyperactivity universally characteristic of this phase of life and should be similar in any human population. This does not seem to be the case in the San Pedro de Atacama population, since late adolescents and early adults do not present any peak of risk for fractures.

3. The virtual absence of fractures in the large sample of infants and children is indicative of an absence of traumatic child abuse in San Pedro de Atacama, a conclusion also reached by Lovejoy and Heiple (1981) for the Libben population.

4. Despite an elevation of fracture risk after the age of 45 years, few old-age fractures were actually observed in San Pedro de Atacama because of the low survivorship after that age, again a fact also emphasized by Lovejoy and Heiple (1981) for the Libben site.

5. The population of the Libben site was twice more affected by postcranial fractures than that of San Pedro de Atacama. Assuming conclusion 1 is correct, this means that the life style of the Libben population was much more stressful and risky than that of the Atacameneans. Although both populations were sedentary, they present very different subsistence patterns. In Libben, subsistence economy relied primarily on hunting, fishing, and gathering, while in San Pedro de Atacama sustenance was based on cultivation of small, irrigated gardens and camelid herding. We believe that the subsistence pattern adopted by the Atacameneans involved much more predictability in terms of body exposure to risk of trauma than was the case with the Libben population.

6. Last but not least, we totally agree with Lovejoy and Heiple (1981) that the systematic observation and recording of frac-

ture data can provide valuable information in analysis of human populations when properly adjusted for demographic variables.

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